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(54) METHOD AND APPARATUS FOR EVALUATING X-RAY IMAGE

(57)Abstract:
PURPOSE: To accurately compare the X-ray images of an object to be examined taken with the elapse of time, by a method wherein the coordinates of at least four points in each of at least two stored X-ray images are allowed to coincide with each other substantially by a projection converting method and shadow density is corrected by a density converting method based on the X-ray image of a standard substance.
CONSTITUTION: At least two X-ray images taken with the elapse of time at the time of treatment are stored in a memory means. A projection converting method used in the conversion of coordinates indicates four points in one image among a plurality of images and, when the coordinates of four corresponding points in the other image are indicated, the parameter of projection conversion is determined and the coordinates of four points of both images can be allowed to coincide with each other after conversion. In density conversion, a function made approximate in the relation between the shadow densities of the images of the respective standard substances corresponding to a plurality of images and the thicknesses of the standard substances is used to allow the shadow density pattern to the thickness of the standard substance in one image to coincide with that to the thickness of the standard substance in the other image. The image after the conversion of coordinates and that of density are applied and an X-ray image desired to be compared are displayed on a display means.

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1. Title of the Invention:

Method and Apparatus for Evaluating X-ray Picture

2. Claim:

(1) A method for evaluating an X-ray image of an object to be examined, by using at least two X-ray images of substantially the same part of a body where said object is present, said at least two images being taken at different times together with a reference substance;

wherein the shading densities of corresponding portions of the respective ones of said at least two X-ray images are compared with each other by:

(i) inputting said at least two X-ray images through image inputting means and storing said images by means of storage means;

(ii) substantially registering at least four corresponding points on each of the stored at least two X-ray images by projection transformation;

(iii) correcting, by density conversion with the X-ray images of the reference substance used as a reference, the shading densities of the stored at least two X-ray images; and

(iv) displaying the stored at least two X-ray images and the projection-transformed, density converted X-ray images.

(2) The X-ray image evaluating method according to Claim 1 wherein said projection transformation comprises: designating four points forming a quadrilateral on one of the stored, at least two X-ray images and reading coordinates of the respective four points; designating four points forming a quadrilateral on another one of the stored, at least two X-ray images and reading coordinates of the respective four points; determining projection transformation parameters from the coordinates; and registering the four points on said one X-ray image with the four points on said another X-ray image.

(3) The X-ray image evaluating method according to Claim 1 wherein said density conversion comprises: making a thickness-to-shading density pattern of the reference substance in one of the stored, at least two X-ray images coincide with a thickness-to-shading density pattern of the reference substance in another one of the stored, at least two X-ray images, by the use of a function approximating the relationship between the shading density and thickness of said reference substance in the stored, at least two X-ray images.

(4) The X-ray image evaluating method according to Claim 1 wherein said displaying comprises displaying said X-ray images in color, using colors predetermined for respective ones of a plurality of shading density levels of the X-ray images.

(5) The X-ray image evaluating method according to Claim 1 wherein said object to be examined is bone.

(6) An apparatus for evaluating an X-ray image of an object to be examined, by using at least two X-ray images of substantially the same part of a body where said object is present, said at least two images being taken at different times together with a reference substance; said apparatus comprising:

(i) image inputting means and image storage means for inputting and storing said at least two X-ray images;

(ii) projection transforming means for substantially registering at least four corresponding points on each of the stored, at least two X-ray images;

(iii) density converting means for correcting the shading densities of the stored at least two X-ray images, by referencing the X-ray images of the reference substance; and

(iv) display means for displaying the stored at least two X-ray images and the projection-transformed, density converted X-ray images.

3. Detailed Description:

[Industrial Field]

This invention method and apparatus for evaluating an X-ray image relating to an object, e.g. bone, to be examined, and, more particularly, to a method for quantitatively comparing X-ray images of, for example, a fractured bone, when treating such bone, and also to an apparatus for use therein.

[Prior Art]

In a prior art method for evaluating temporal changes of a bone, such as formation of callus or bone atrophy around it, occurring during treatment of bone fracture, X-ray images of, or monochromatic pictures taken by X-raying a bone when it is broken, immediately after a bone-setting operation is provided, and at times during treatment, are compared and observed with eyes.

In such method, it is very difficult to accurately determine the bone states from the densities of X-ray images due to restrictions due to physical properties of the X-ray used and the monochromatic pictures taken by X-raying. Due to multiple-wavelength property of photographic X-rays, influences of diffused rays, defocusing, and fogging in photographic films, for example, a range in which the relationship between the thickness of a sloping or stepped reference substance of aluminum, for example, and the shading density, or darkness of the X-ray image is linear. Also, the area of a portion radiated with homogeneous X-ray is small. Furthermore, it is very difficult to take pictures of the same part in the same size and shape under the same X-raying conditions. Under such circumstances, simple comparison of densities of X-ray images can provide only very indefinite evaluations.

[Object of the Invention]

An object of the present invention is to provide a method for evaluating X-ray images which enables accurate comparison of X-ray images of an object to be examined, such as a bone, X-rayed at different times, and an apparatus therefor, which method has been considered to be difficult.

[Arrangement of the Invention]

The inventors have diligently made studies to realize the object, and found that it is very effective to video-input two or more X-ray images to be compared and evaluated with a video camera for storing the densities of the inputted images in memory means of a computer, to provide video-processing, such as coordinate transformation and density conversion, for the stored X-ray images in the computer, and to make comparative studies on the resulting X-ray images.

Specifically, there are provided by the present invention:

a method for evaluating an X-ray image of an object to be examined, by using at least two X-ray images of substantially the same part of a body where said object is present, said at least two images being taken at different times

together with a reference substance;

wherein the shading densities of corresponding portions of the respective ones of said at least two X-ray images are compared with each other by:

(i) inputting said at least two X-ray images through image inputting means and storing said images by means of storage means;

(ii) substantially registering at least four corresponding points on each of the stored at least two X-ray images by projection transformation;

(iii) correcting, by density conversion with the X-ray images of the reference substance used as a reference, the shading densities of the stored at least two X-ray images; and

(iv) displaying the stored at least two X-ray images and the projection-transformed, density converted X-ray images; and

an apparatus for evaluating an X-ray image of an object to be examined, by using at least two X-ray images of substantially the same part of a body where said object is present, said at least two images being taken at different times together with a reference substance; said apparatus comprising:

(i) image inputting means and image storage means for inputting and storing said at least two X-ray images;

(ii) projection transforming means for substantially registering at least four corresponding points on each of the stored, at least two X-ray images;

(iii) density converting means for correcting the shading densities of the stored at least two X-ray images, by referencing the X-ray images of the reference substance; and

(iv) display means for displaying the stored at least two X-ray images and the projection-transformed, density converted X-ray images.

Now, the present invention is described in detail.

According to the present method, at least two X-ray images photographed at different times are used in treating fractured bones and parosteal chondrosarcoma, for example. The X-ray images are produced by placing substantially the same part of a body including an object to be examined, e.g. a bone, on X-ray films, together with a reference substance, e.g. an aluminum staircase including twenty steps each being 1 mm high (minimum 1 mm and maximum 20 mm), or an aluminum slope.

These X-ray images, or monochromatic photographic pictures obtained by X-ray photography, are inputted to image input means in the form of transmitted light obtained by projecting light rays, and, then, stored in memory means. The image input means includes a television camera, for example. It is preferred that such image input means have a shading correction capability, and ITC-2600 available from Ikegami Tsushinki Co., Ltd., for example, may be used therefor. A personal computer, e.g. PC-8900 available from EDECK Co., is suitable as the X-ray image memory means in view of processing ability and cost. When storing an image, 220 x 220 pixels/picture may be processed to any of integral values of 256 gradations, but it is desirable that a machine language be used for portions for which a higher processing speed is required, as in the later-mentioned image processing.

The image inputted and stored in this manner is subject to problems caused by the properties of an optical system, lack of uniformity of a light source, and shading associated with the video camera, which are used to take in the image, and it is difficult to place a plurality of X-ray images on the same location on the light source. Accordingly, error in positioning of the images and reading densities is inevitable.

According to the present invention, coordinate transformation by projection transformation is employed to align at least four points of each X-ray image with the corresponding points on the other X-ray images, and density conversion referenced to the density of an X-ray image of the reference substance is employed to correct the respective X-ray images for density difference and error occurring at X-raying and reading. The order in which the coordinate transformation and the density conversion are carried out is arbitrary.

Such image processing including the coordinate transformation and density conversion is carried out by means of a computer, which suitably is a personal computer PC-9801 available from NEC, for example.

The projection transformation used for coordinate conversion is to convert a quadrilateral into any desired shape of quadrilateral, for example, and can enlarge and reduce the size of a figure, rotate the figure, and correct linear distortion. Specifically, four points on one of a plurality of input images, and coordinates of four points on other one of the images are specified, whereby parameters for the projection transformation are determined, and the coordinates

of the four points of the respective images can be registered after the transformation. A microprocessor requires a long time for the image processing for such transformation, and, therefore, programs incorporating a machine language are suitable. Further improvement of processing efficiency can be obtained by the use of a numerical operation processor.

As described above, there are many factors affecting the shading of photographic films, such as differences in voltage applied to a bulb, differences of films, sensitized paper sheets and screens, and differences in performance of developing machines. Accordingly, highly reliable X-ray image comparison and evaluation cannot be realized if image correction by density conversion is not provided to match the density slopes.

In order to carry out the density conversion, a function approximating to the relationship between the density of the image of the reference substance associated with the respective ones of the stored images and its thickness, is used to make the density-to-thickness pattern of the reference substance on one of a plurality of images coincide with that of another one of the images. As the approximating expression, a quadratic or cubic functions can be used, but, for higher accuracy, a function expressing an approximation expression including an S-shaped curve which fits to the relationship between the thickness of the reference substance and its density and into which shifts occurring at the inputting are incorporated, may desirably be used.

With the apparatus of the present invention, when an image is taken in, being allocated to an integral value of 256 gradations of form 0 to 255, as previously mentioned, a portion outside the 256 gradation range is trapped and stored as being 0 or 255. Then, the thus trapped 0 or 255 is treated similar to the true 0 or 255, and, therefore, comparison regarding such portion is meaningless. Accordingly, it is desirable that the levels of the compared portions should not be at the value of 0 or 255 when they are inputted through the video camera.

According to the present invention, an X-ray image to be compared and the thus coordinate-transformed, density-converted X-ray image are displayed on display means. The respective images are preferably displayed in color, using colors predetermined for respective ones of plural steps, into which the density of an image is classified, so that the density difference can be clearly seen. The

display means may be a conventional television cathode ray tube, a liquid crystal display and the like.

When comparing images, the difference or ratio between the densities of corresponding pixels of the images may be determined and displayed in association with the position of the pixels.

When the object to be examined is not a bone, but a soft tissue part, what is called quantum noise may be dealt with. In such case, it is desirable to selectively set and display only those regions in the X-ray images which are to be compared and evaluated, display the density differences or density ratios for portions in the selected regions in color, and also display the proportions of such portions to the entire region in the form of graph and the like.

It is preferable to perform coordinate transformation and density conversion prior to the selective setting of the regions to be compared and displayed, but they may be done after the selective setting.

[Effects of the Invention]

According to the present invention, comparison of plural X-ray images of the same object to be examined photographed at spaced times can be made with high reliability, which has been considered difficult. In particular, it has made it possible to easily and accurately evaluate bone-fracture during treatment with X-ray images taken at time intervals.